AD-A169 241 AN ACCURATE METHOD TO EXTRACT SPECIFIC CONTACT RESISTIVITY USING CROSS BRIDGE KELVIN RESISTORS(U) STANFORD UNIV CA DEPT OF ELECTRICAL ENGINEERING 1/1

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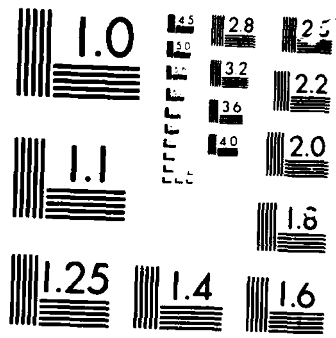
1.0
4.5
5.0
2.8
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3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

An Accurate Method to Extract Specific Contact Resistivity Using Cross Bridge Kelvin Resistors

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ABSTRACT

The cross bridge Kelvin resistor structure is used to extract true interfacial specific contact resistivity(ρ_c). Two dimensional simulations demonstrate that the sub-linear behavior of the measured contact resistance versus contact area on a log-log plot is due to current crowding around the contact which results from the contact window size being smaller than the diffusion width. The effect is more pronounced for low values of ρ_c. Excellent agreement has been found between the simulations and measured data of contact resistances. An accurate value of ρ_c has been extracted for the case of PtSi to N+ polysilicon contacts.

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I. INTRODUCTION

Cross bridge Kelvin resistor structure, as shown in Fig.1, is widely used for the measurement of contact resistance and the extraction of specific contact resistivity[1]. Measurement provides a Kelvin potential V and a total current I. The ratio $\frac{V}{I}$ is the Kelvin contact resistance R_c. In the ideal case-- where the contact is as wide as the diffusion tap, the specific contact resistivity ρ_c can be calculated directly as the product of the contact area(A) and R_c. This implies that R_c should be inversely proportional to A. In other words, a log-log plot of the Rc vs. A should have a slope of -1. Proctor et al.[1] discovered in their study of pure Al to Si contacts that the log-log plot exhibits sublinear characteristics-- the slope is not constant and significantly less than 1. They attributed this effect to the non-uniformity of the contact interface: the pitting of Al into Si changes the effective area and the sheet resistance underneath the contact window. Only for the case of Al-1.5%Si to Si contacts did Proctor find a constant slope of -1. In other studies of AlSi to Si contacts[2-3], where pitting was insignificant, the sublinear characteristics are still observed. It has been suggested[4-6] that if the diffusion tap is wider than the contact window, part of the current which flows from the diffusion tap up into the contact window, crowds around the diffusion tap area not underneath the contact window. This current crowding effect explains the sublinear behavior seen in both the pure Al and the AlSi cases. This effect is more pronounced if the diffusion sheet resistance(R_s) is large, ρ_c is small or the feature sizes are large.

Recently, two dimensional(2-D) computer simulations[5-6] have been utilized to study the effects of current crowding around the contact. We have demonstrated that the $R_c A$ value always overestimates ρ_c, even for a uniform contact interface. Finetti et al.[7] simulated the pure Al case mentioned above. They concluded that the current crowding alone cannot account for the sublinear behavior and thus a physically meaningful ρ_c cannot be extracted. It is the purpose of this letter to report that for low resistance contacts, current crowding does in fact explain the sublinear behavior if pitting does not occur. In that case, it is possible to extract a physically meaningful ρ_c which is independent of contact area and diffusion tap width.

II. EXPERIMENT AND SIMULATIONS

The cross bridge Kelvin resistor and its cross-sectional view are shown in Fig.1. The fabrication procedures are as follows: a thin layer of polysilicon was deposited on thermal SiO_2 grown on a lightly doped Si wafer. A $POCl_3$ predeposition was done at $1050°C$ for 20 minutes followed by a drive-in at $1000°C$ for 1 hour. This resulted in uniform concentration of phosphorus in polysilicon. Islands are formed by plasma etching to achieve precise values of the diffusion tap width w. Undoped LPCVD SiO_2 was then deposited and contact holes to the N+ polysilicon were opened by plasma etching. A thin layer of Pt was deposited and $PtSi_2$ was formed in the contact area at $375°C$. Unreacted Pt was then removed by aqua-regia. Al-1.5%Si was sputtered to form the metallization.

The sheet resistance of the polysilicon(R_s) was measured to be 11.0 Ω/sq.. The contact window sizes(l) varied from 5.0 μm to 65 μm. The diffusion tap widths(w) were maintained 5 μm larger than l. This allowed a large number of contact structures in addition to a wide range of $\frac{w}{l}$ ratios. Fig.2 plots the measured R_c vs. A. The highest and lowest values of R_c measured across the wafer set the error range of the measurements. The error range of l was also estimated. The dependence of R_c on A is clearly sublinear. The simple $R_c A$ method to obtain ρ_c is not valid since the slope is not constant. The extraction of the true ρ_c becomes nontrivial. By assuming the sublinear dependence of R_c on A to be due to current crowding, an extremely good fit is possible.

In our earlier work[6], 2-D simulations of the Kelvin resistor structure have been performed to show that the measured R_c is always greater than $\frac{\rho_c}{A}$. The difference strongly depends upon the values of R_s, ρ_c, w and l. The same analytical techniques have been used here to calculate R_c for different values of w and l using ρ_c as a fitting parameter. ρ_c was varied from 2.33E-7 $\Omega\, cm^2$ to 2.33E-9 $\Omega\, cm^2$. The results are represented by the solid curves in Fig.2. The simulations accurately track the general sublinear bending of the measured data. The excellent agreement of theory and data of the R_c dependence on contact area enables the extraction of the true value of ρ_c. The extracted ρ_c value of 4.5E-8 $\Omega\, cm^2$ gives the best fit to the measured data in Fig.2. It is observed that ρ_c is independent of contact area. For the limiting case with w equals l, the ideal Kelvin resistor predicts the slope to be unity since there would be no current crowding. This is illustrated by the dotted curve in Fig.2.

The difference between the ideal and the nonideal cases are substantial and most pronounced for large contact areas.

The next step is to verify that the true ρ_c is independent of the diffusion tap width, w. R_c values were measured on structures with w ranging from 7.5 μm to 60 μm while l was kept constant at 5 μm. Fig.3 plots measured R_c vs. w. The accurate tracking characteristics are again observed between measured data and the simulations. The previously extracted value of ρ_c (4.5E-8 Ω cm^2) fits the data accurately. Note that the relationship between R_c and w is extremely nonlinear for this low value of ρ_c. When $w = l = 5$ μm, as shown in Fig.3, R_c has the ideal value of 0.18 Ω (ρ_c/A). As w increases from 5 μm, R_c increases rapidly indicating the strong current crowding effect around the contact. When $w >> l$, the increase of R_c slowed down. This phenomena is similar to the 'smoothing' effect mentioned in ref.[6]. Higher values of ρ_c and lower values of R_s will produce curves which are less nonlinear. As ρ_c becomes sufficently large, R_c will be independent of w and a flat curve should appear.

III. DISCUSSIONS

The study of R_c as a function of A and w demonstrates the following points. For uniform interface contacts, a physically meaningful ρ_c can be extracted despite strong effects of current crowding. This ρ_c is independent of l and w--in other words, only dependent on the material parameters such as surface doping, surface cleanliness and contact metal type. As contacts shrink, the total resistance contributed by the contact becomes ρ_c / A in the limit[8] which agrees with the scaling law that contact scales with area[9]. Pessimistically high values of contact resistances have been predicted for the VLSI contacts of future generations because the values of ρ_c have been grossly overestimated. For uniform interface contacts, the simple $R_c A$ technique in cross bridge Kelvin resistor measurements gives erroneous values of ρ_c. The values measured this way can differ from the real ρ_c by nearly 2 orders of magnitude. In general, the Kelvin contact resistance R_c is not inversely proportional to A and exhibits nonlinear dependence on w and l. This implies that the exact values of R_s, w, l must be known for each cross bridge Kelvin resistor structure, not just the contact area.

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Figure captions

Fig.1The Kelvin resistor structure and its cross-sectional view. The total current is I and the Kelvin potential is V. The N+ polysilicon is deposited on SiO_2. $PtSi_2$ is formed between Si and AlSi.

Fig.2Kelvin contact resistance vs. contact area. The top set of curves are for diffusion tap width(w) larger than contact window size(l) by 5 μm. The sheet resistance of the N+ polysilicon is 11.0 Ω/sq.. The simulation parameter ρ_c is varied from 2.33E-7 to 2.33E-9 $\Omega\ cm^2$. The solid lines are the simulations and the crosses are measured data. The dotted curve represents the ideal case where w equals l.

Fig.3Kelvin contact resistance vs. diffusion tap width. The contact window size(l) is fixed at 5.0 μm. The diffusion tap width(w) is varied from 7.5 to 60 μm. The sheet resistance of N+ polysilicon is 11.0 Ω/sq..The solid lines are the simulations and the circled points are the measured data.

A-1

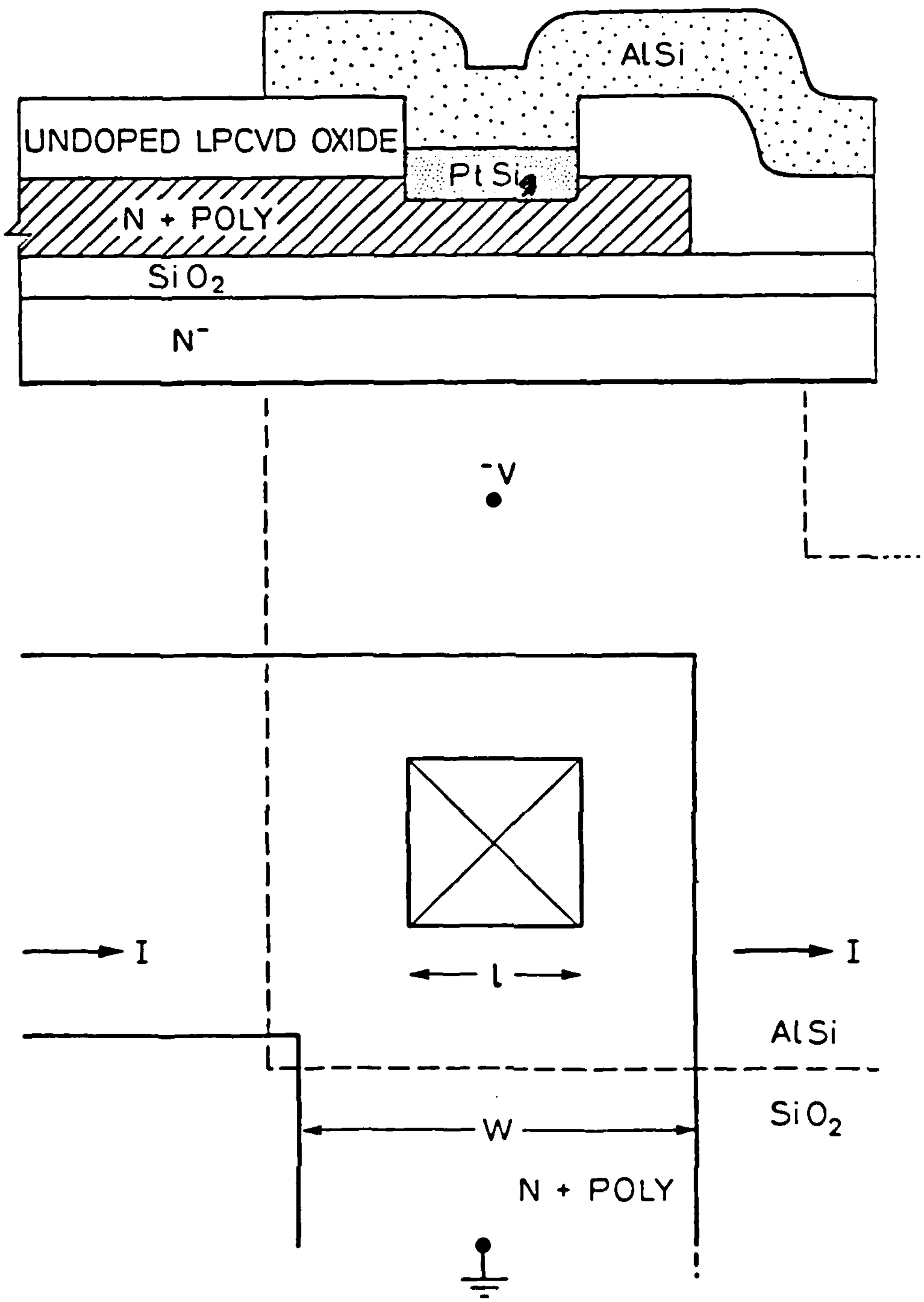
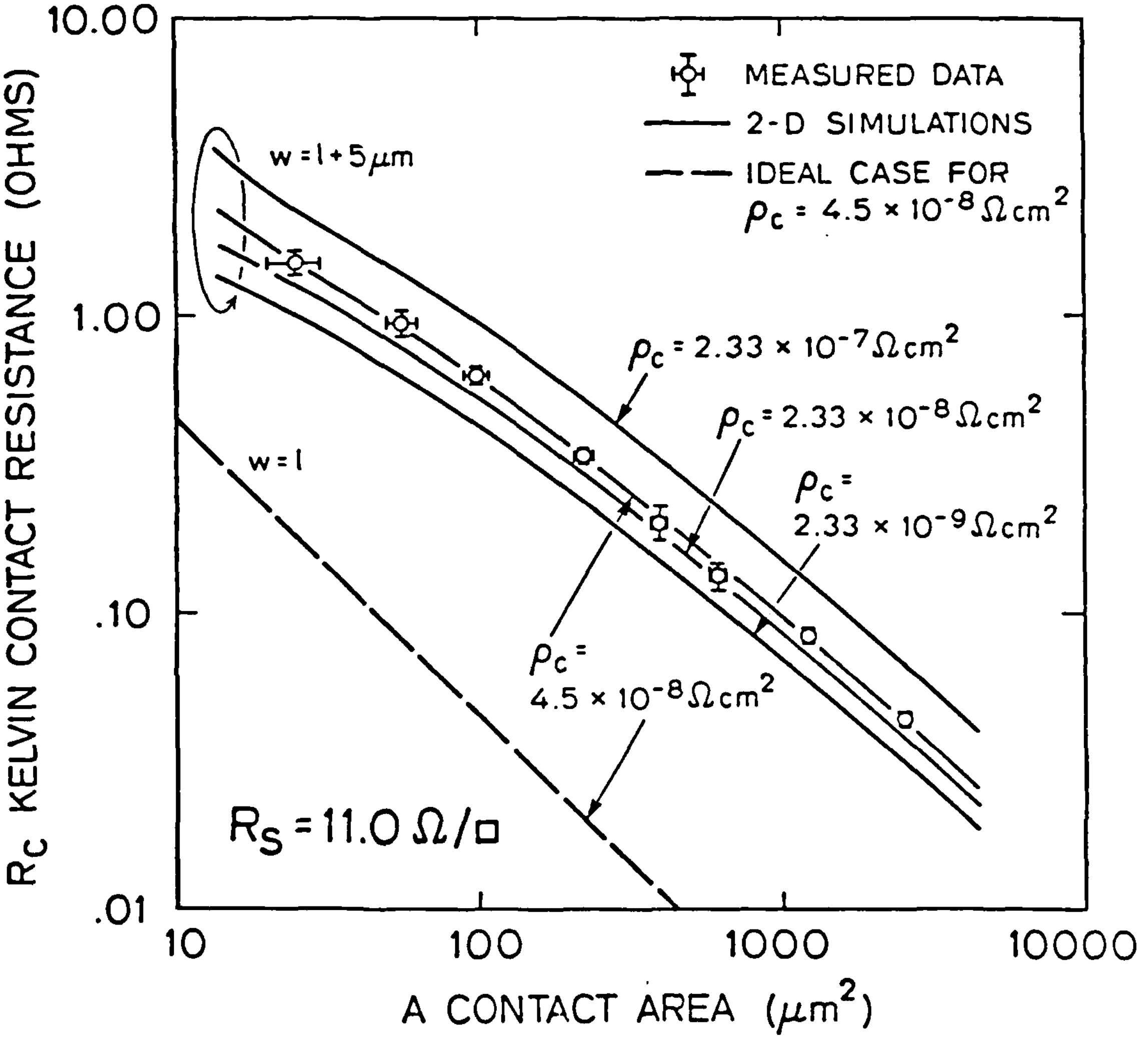
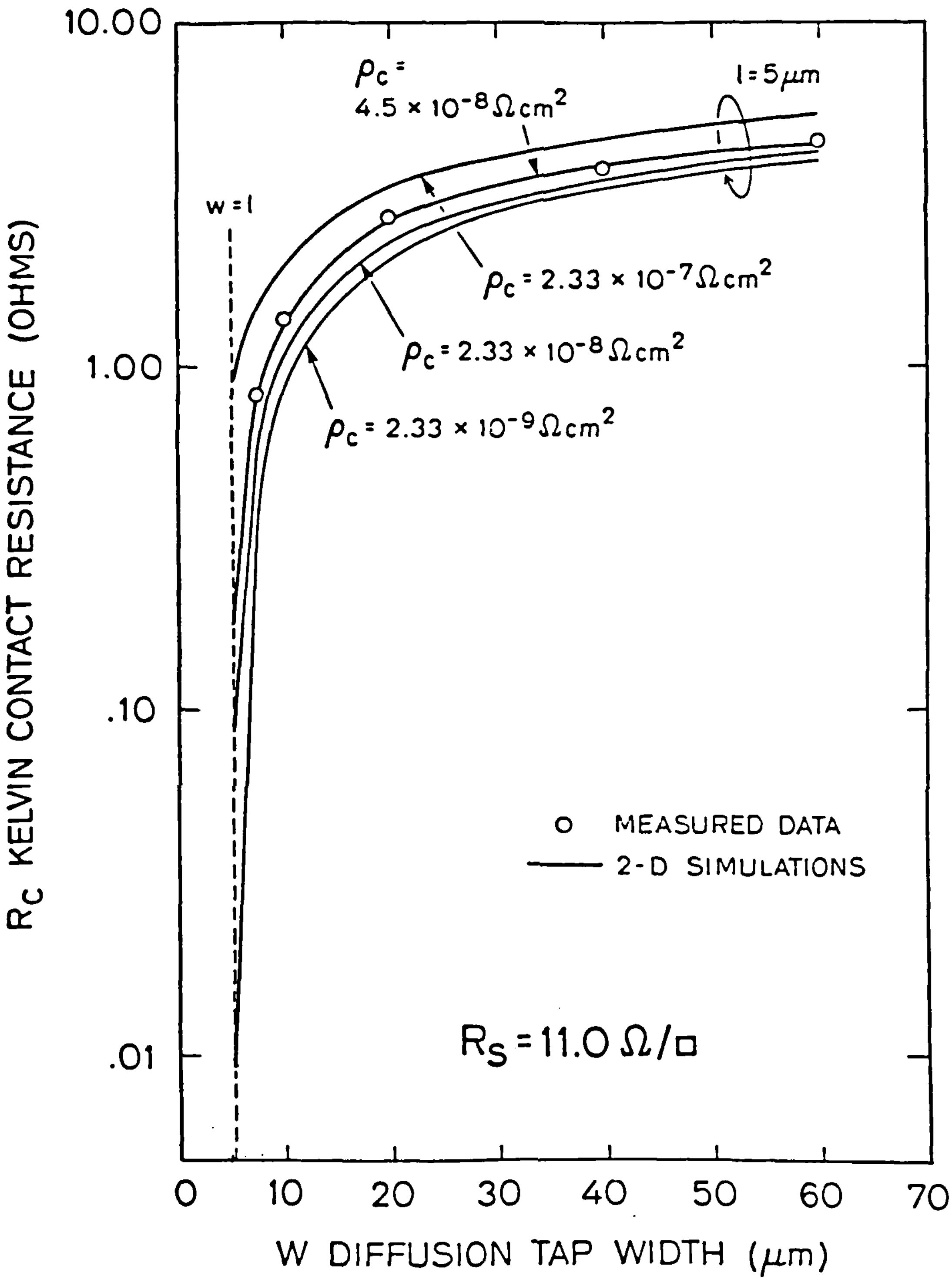

AlSi
UNDOPED LPCVD OXIDE
Pt Si
N + POLY
Si O2
N⁻
-V
I
l
I
AlSi
W
Si O2
N + POLY

Fig.1



MEASURED DATA
2-D SIMULATIONS
IDEAL CASE FOR
ρc = 4.5 × 10⁻⁸ Ωcm²
w = 1+5 μm
w = 1
ρc = 2.33 × 10⁻⁷ Ωcm²
ρc = 2.33 × 10⁻⁸ Ωcm²
ρc = 2.33 × 10⁻⁹ Ωcm²
ρc = 4.5 × 10⁻⁸ Ωcm²
Rs = 11.0 Ω/□
Rc KELVIN CONTACT RESISTANCE (OHMS)
A CONTACT AREA (μm²)
10.00
1.00
.10
.01
10
100
1000
10000

Fig.2



10.00
1.00
.10
.01
0
10
20
30
40
50
60
70
R_C KELVIN CONTACT RESISTANCE (OHMS)
W DIFFUSION TAP WIDTH (μm)
w = l
l = 5 μm
ρ_c = 4.5 × 10^{-8} Ωcm^2
ρ_c = 2.33 × 10^{-7} Ωcm^2
ρ_c = 2.33 × 10^{-8} Ωcm^2
ρ_c = 2.33 × 10^{-9} Ωcm^2
o MEASURED DATA
2-D SIMULATIONS
R_S = 11.0 $\Omega/\square$

Fig.3

END

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